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Origin of car enthusiasm and alternative paths in history

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ABSTRACT

How can we explain the formidable success of the car all over the world? It is suggested here that the historical origin is key to the root of this enthusiasm. From a climate change mitigation perspective car culture is a difficult problem, but why is that so? This paper presents a framework of interpretation based on the literature of the birth of the American car culture about one hundred years ago. Agency, not the least on the part of the user, technological choice, and industrial links are emphasized and put together in a framework called "forks and links". This framework is tested as a narrative in the second part of the paper. It is argued that the car belongs to a product category with which active users can change their lives, while fuel and propulsion is just an input. A desired capacity for touring was decisive in the choice between gasoline and electric cars.

1. Introduction

1.1. Aim, questions and background

The car is perhaps the most successful innovation ever, spreading all over the world as it seems, despite well-known backsides to this success, not the least in light of climate change. The strive towards sustainability today directs policies that aim to reduce the car's environmental effects. Many national strategies are similar to that of the United Nations' "Avoid-Shift-Improve Approach": Reduce the need for transport, shift to other modes of transport, and improve the environmental characteristics through more energy efficient engines, renewable fuels or electric propulsion.[2]

This study concentrates on explanations of the formidable success of the automobile and the choice of propulsion and fuel in the early 1900's in the USA. Nowhere did automotive use become so widespread so fast as in this country – in the late 1920's three out of four cars in the world were American. It is a good case for a study of car enthusiasm also because of the volume and quality of the literature on these issues.[3]

The American case is very good for gaining a deeper understanding of the problems we face today concerning transitions to sustainable transport paths. The huge success of the automobile is one aspect. What do we know about the love of the car, how did it originate? Another field of inquiry for which the US case is suitable concerns the electric car. It is well known that three types of cars existed side by side at the turn of the century, but why was the electric marginalized? A third focus is that of choice of fuel. That alcohol, or ethanol, was one possible alternative, is not so well known, but it is important considering discussions today around renewable fuels.

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[2] UN (2016); One synthesizing reference is GEA (2012), chapter 9" Transport" and 20" Land and water: Linkages to bioenergy".

[3] Yergin (1991), pp 208–209.

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When answers are based on close looks at the artifacts themselves there is an obvious danger of ending up with an isolated technical explanation. Social scientists and inter-disciplinary scientists often look for contextual or social explanations. Sometimes the reaction against “technological determinism” goes too far so that technical aspects are denied altogether.

The aim of this study is to present a theoretical framework that can explain both why the electric car was marginalized, and why the car in general was such a huge success. An explanation open for choices between different technologies, but also able to explain why one becomes dominant in the dynamically conservative sense we associate with the socio-technical regime in the multi-level perspective.[4]

I suggest a new frame of interpretation based on “development blocks” and McCarthy's dialectical enrichment of Veblen's concept “conspicuous consumption”. Characteristic of this frame is that the user and agency take prominent place, together with a distinction between consumer products with which users can develop their social and everyday life and other consumer products. Among the latter we can find necessities for the former where the dynamic development instead emanates from possible inter-industrial complementarities. This framework, named Forks and Links, will be presented in Section 2:

Why was the car so popular? Why was the electric car marginalized? Could there have been another fuel for the winning car?

My suggested theoretical framework organizes a narrative in Section 3, with empirical data taken from the literature and from descriptive statistics. This framework and research questions have guided the choice of data for this narrative. Three theoretical issues are discussed in the following section: The idea of hybridization and the normal car as city car, a cornerstone in David Kirsch's and Gijs Mom's interpretation; The difference between the active user and “user-roles” suggested by Schot, Kanger and Verbong; And a critique of Geels' “de-alignment, re-alignment” pathway. The concluding Section 5 answers research questions, with one addition on policy implications.

My interest in the historical origin of the car and the use of gasoline as fuel was raised when I compared the effects of the oil crises in the 1970's on the use of heating oil and gasoline in Sweden. Despite that prices increased for both, reactions were quite different, as can be seen in Fig. 1.[5] There must be something special with the car.

2. Forks and links

2.1. Path dependence

According to the theory of path dependence even inferior technologies can survive due to chance at some early point in the development. Paul David and W. Brian Arthur have proposed concepts for rigorous definitions of “path dependence” and “increasing returns to adoption”. The debate with Stan Liebowitz and Stephen Margolis is quite revealing, as the latter cannot accept that the rational actor chose an inferior good. Inferior technologies are looked at as dead-ends and failures. In this perspective history is uninteresting, as it can only tell us about obstacles and delays for the inevitable rational process. Liebowitz and Margolis defend the basic assumptions of neoclassical theory, but even though Paul David wanted to attack these assumptions he unfortunately formulated his theory in a similar type of language, in terms of probabilities and with parallels to physics, arguments that are convincing to mathematical economists who believe in equilibria. David's insistence on a precise definition has narrowed the usefulness of “path dependence” for most historical cases. It is suitable only for technologies like keyboard arrangements, railway gauges and other design standardizations fixed at an early point in time.[6]

When it comes to comparisons of complex matters – small technical systems like steam cars, electric cars and cars with an internal combustion engine, or large technical systems like the automobile with its supporting infra- and superstructure – it is hard to determine what is superior and inferior. Systems are complex, and they often change quite rapidly in early phases. And competing large technical systems rarely exist side by side. But even more important is what Loeb indicated, that consumers preferred some capabilities or characteristics of the many types of cars that appeared in the 1890's and 1900's. A car with touring capacity became “the car”, the dominant expectation, which marginalized other types of cars.[7]

What we need is a theory of path dependence where diversity is reduced or lost when users develop their preferences and a few or one design becomes dominant, and the system grows with stronger links to complementary investments and interdependencies with other industries, making it increasingly difficult to change direction. This could be investments in roads that compete with other modes of transport, divestments in sidewalks, bicycle lanes and room for public transport, links to the oil industry and mutual development and dependence between industries, etc., that excludes options that were at hand earlier. Technological underdevelopment (the battery as starter battery makes the development of batteries dependent on the gasoline car), and divestments in other modes of transport lock-in both users and producers to a narrow path. I believe many researchers need a theory like that, but David and Arthur did not provide it.

[4] A formulation of Geels is “dynamically stable” (Geels, 2012). It is not a big difference to replace “stable” with “conservative”, but the latter is more in line with Hughes' distinction between conservative and radical innovations, and Rosenberg's case of changes in old technologies as defense against challenges from new technologies.

[5] How heating oil was replaced is quite a complex story involving both district heating and electric heating and a struggle between CHP and nuclear power. For a glimpse of this see Di Lucia and Ericsson (2014).

[6] David (2002); Liebowitz and Margolis (1999); Puffert (2008).

[7] Loeb (1995).

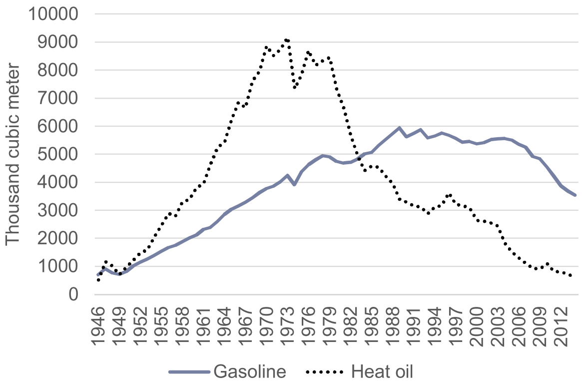

Fig. 1. Use of gasoline and heating oil 1946–2014 in Sweden. Thousands of cubic meters.
Source: SPBI (2015).

2.2. Development blocks

Fork refers here to a choice of path that historical actors must have made, and link refers to complementarity between two industries or two technologies. The latter has been conceptualized as "salient" and "reverse salient" by Thomas Hughes, and as "development block" by Erik Dahmén. Hughes pictured the phenomenon of the reverse salient in terms of system, where one component was at the front and others lagged behind so that further development of the system depended on development of those lagging and this necessity appeared among the actors as "critical problems" to solve.[8] That Edison searched for a better battery fits perfectly well into the concept of "critical problems", but he failed to find a solution suitable for the electric car as a system.

Dahmén's idea of "development block" is quite similar but in terms of industries, and complementarities between industries. A development can be "premature" if the complementary ones are missing, according to Dahmén, and thus there is a "structural tension". A development block ex ante is what the historical actors can see, imagine and act upon, while a development block ex post is what all those decisions perhaps ended up with. According to Lennart Schön "complementarities" in the economy raises the value of both sides – the whole is bigger than the sum of its parts. They create leaps in the economy as development blocks are created around innovations that changes the complementary relations. They also create imbalances and bottlenecks as actors discover the need for new competences, new equipment or new organizations in light of the complementarity. Development blocks appear at different scales, from micro to societal.[9]

When a conglomerate was formed in New York by the street-car monopoly and major electricity providers to expand the electric taxi business in 1899, and when the Electric Vehicle and Central Station Association was formed in 1909, described in detail by David Kirsch, they were examples of development blocks ex ante, while such blocks ex post never were realized.[10]

2.3. Agency and interplay between users and manufacturers

In order to keep this frame non-deterministic it must open the door for initiative and decisions of historical actors. McCarthy's view is helpful in that it allows us to see "supply and demand" not as anonymous and balancing forces, but as real people and organizations exploring and offering new technologies. Somehow a quite expensive and immature consumer product became extremely popular, but choices at one stage narrowed the choice set at the next.[11]

McCarthy not only make use of Veblen's "conspicuous consumption" but also develops this idea. He fills the empty categories of "supply and demand" in economics with agency: Emotions, search and choice. The have-nots both hated and loved the car, and Ford tried several models before he found a winning concept. Manufacturers offered cars with different capabilities and characteristics within the limits of technology at the specific point in time, but buyers chose those capabilities and characteristics they preferred. In races and reliability runs rich people showed what a car could be, and this started a dialectical process where both car-owners and car-makers took initiative, i.e. actors were the origin of events, not caused by something else outside or behind actors, but the root itself. There were many choices to make, and at each point a different choice could have been made. When historians go further and try to explain the strive for distinction and entrepreneurial initiative by circumstances, agency is diminished or even lost and the cause is reduced to "structure" or "culture".[12]

[8] Hughes (1989/2004), pp 71–74.
[9] Dahmén (1989); Schön (2006), 53–61.
[10] Kirsch (2000a), pp 53–61, 94–96.
[11] McCarthy (2007).
[12] On the object of the historian's inquiry, see Carr (1961), pp 44–55. For an interesting philosopher's view on social structure and human agency, see Bhaskar (1989), pp 92–95.

2.4. Concepts and hypothesis

This study follows the Multi-Level Perspective tradition in general, and borrows concepts from other theories as well. However, working with this idea it has become obvious that “the active user” is distinctive and in need of a special place as a new concept. The user may be the consumer, the buyer, but it is not the same category. The user actively uses the product and in that develops his or her social and everyday life. It is a matter of exploring what can be done with the product, testing, improvising, experimenting. At some point in time someone put a tent in the backseat of the car and went for “autocamping” for the first time ever – a “new combination”. The similarity with the mobile phone and development of new habits around it is quite obvious. Thus, there is need for a distinction between different types of products. Far from all consumer products can be used in this multi-functional and experimental way, quite the contrary many of them are just necessary for the use of the former. Perhaps we can call them ‘exciting’ and ‘boring’ products: Exciting because the user can innovate his or her social and everyday life, and boring because the product is just a necessity.

Forks are situations in historical time when choices between alternatives are made in one way or another. The dominance of one alternative has not yet been settled. Supplier’s link to consumers is decisive when the product can be actively used. Users explore what can be done with the product and at the same time develop their own social life and preferences, often as distinctions between social groups. The more users can do with the product, the more popular the product becomes, and this gives a strong momentum for the innovation, raising it from niche to regime. For this to occur manufacturers and sellers must foresee future use and have a feeling for social interplay, experimenting with different designs in order to connect to different user groups. When the product cannot be used in an exploring and experimental way, but is merely a necessary input for the use of the ‘exciting’ ones, the link to the consumer is not decisive while that to other, complementary, industries is. Energy always belongs to this second category of ‘boring’ innovations, and the outcome of struggles between different energy carriers is determined by the ability to adjust to the uses of the ‘exciting’ product.

3. Emergence of the car and its fuel

Public transport and tourism are taken here as starting points of a narrative around the early car and its fuel. Both were new in the 19th century, and as categories they are open as to what technology is used. There were several technologies used for public transport, and choices among them had consequences for the technological development of, expectations on and alternatives to the car. All studies discuss public transport and touring in relation to the coming automobile. In a world of horses and horse-drawn wagons these two sociotechnical innovations introduced new mobility patterns. Cab-service, or taxi, was part of the old world, a semi-public service.

Two basic innovations	
A	Public transport
B	Tourism

American cities grew in size and people needed to find a cheap way to move back and forth from the center. Railroads had been built since the 1820’s, but steam powered public transport was never accepted in urban areas, according to McShane. Fear of boiler explosions, high speed and smoke may have been grounds for resistance, but primarily because rails rose above street-level, blocking cross-traffic. Local authorities in New York wanted train stations to be outside the city center, and for older stations already situated downtown trains had to switch to horses for the last part of the track in cities. Another solution was to put them aside on elevated railways. For a short while small steamers, “dummies”, were used but were never accepted. An important point McShane wanted to make was that in an era when horses and pedestrians were the norm in urban traffic, steam vehicles, including steam autos, were resisted.[13]

A. Choice of public transport technology	
A.1	Steam train
A.2	Omnibus
A.3	Trolley

Instead horse-drawn carriages were the path chosen in American cities. To begin with the omnibus, a horse-drawn car on the streets. It was introduced in New York in 1831, but widespread introduction of the horse car dated only from the 1850s, according to Hilton: “Previously, cities had been without public transport”. This meant heavy load for the horses, especially since paving of streets was not very common (see Fig. 2). Even though pavements of the time were suitable for horses, they were not suitable for bigger cars. Macadam and cobblestones were common but there were also streets paved with wooden or granite blocks. The share with pavement increased from about 40 per cent in 1880 to more than 80 per cent in 1925, and asphalt had the biggest increase so that it represented

[13] McShane (1994), chapters 3 and 5; McShane and Tarr (2003).

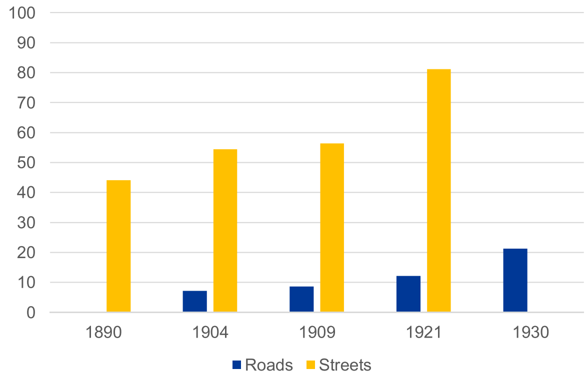

Fig. 2. The share of paved roads and streets in the US, per cent.
Sources: US Bur of the Census (1975) part 2, p 710; McShane (1994), p 59. McShane's data on paved streets covers 12 major cities. The graph shows all paving, not only those suitable for automobiles.

about 40 per cent of all pavements in 1925.[14]

Friction was radically reduced when the car was put on rail (the trolley). Rails for street-cars could be laid flush with the street surface, made possible by the side-bearing rail, a French invention. The horse car started a revolution in travelling and residential patterns in American cities. It had spread to every large US city already by 1860 and made suburban living possible. Technological improvements were made: The weight of the car was reduced considerably in the 1860's, so that typically a 20-passenger car demanded only two horses instead of four. Hauling capacity increased also as stronger horses were bred and used.

However, hilly cities like San Francisco were inaccessible by the horse car. When the number of horses grew problems with animal power followed. Horses must be fed and stabled even when they were not working. An obvious disadvantage was the fouling of streets with urine and excrement. The Great Epizootic of 1872, a respiratory and lymphatic disease, killed 2 250 horses in Philadelphia in three weeks, and hit also many eastern cities. Horse car-owners now became susceptible to horseless solutions.[15]

The very same year the cable car was invented. Now steam power was used, but only for transmitting power to the endless cable pulled through conduits under city streets. Cars moved by hooking on to the constantly moving cable, and releasing it when they wanted to stop. Even though this transport technology spread to some cities, primarily San Francisco and Chicago, it had its drawbacks. Investments in conduits were expensive, and speed was quite low. The vehicle could lose its grip on the cable and proceed out of control. It was quite inflexible as the cable must go in a straight line. This meant that curves had to be traversed at top speed so that the car could get hold of the next cable. "Although at least nine major American cities had cable cars by 1890, such systems still made up only 6 percent of the street railway mileage operated in the United States in that year."[16]

Within just a few years, 1894–1897, the street-car business had changed almost completely to the electric system proposed and demonstrated by F.J. Sprague. It was an overhead system of wires transmitting electric power to trolleys. Investment costs were much lower compared to the cable system, so when Sprague had demonstrated that the system worked in Richmond in 1888 many street car-owners switched to this system. In 1902 only 1 percent of urban transit lines used horses, 1 percent cable cars, 4 percent either elevated railroads or electric subways, and 94 percent electric street cars.[17]

A.3 Choice of horseless street-car system		
A.3.1	Cable car	
A.3.2	Electric street-car	
	A.2.2.1	Third rail
	A.2.2.2	Battery
	A.2.2.3	Overhead

There were several electric solutions. A third rail could be used in the conduit slot that previously had been used for the cable for cable cars, but were very rare, probably due to construction costs for new conduits. Battery street cars was another solution, but according to Schallenberg this type never got more than two per cent of all street car-lines in the US, and this had consequences for battery development and competition between electric and internal combustion cars. The overhead wires became the dominant system, despite the fact that the air was clogged with wires in the 1890's. The telegraph, the telephone, arc-lights, and incandescent lamps gave an increasing mass of wires, and some communities complained when Sprague's system was proposed. Nevertheless, the

[14] Hilton (1969), p 123; McShane (1994), p 59.
[15] Hilton (1969), p 124; McShane and Tarr (2003), pp 182–185.
[16] McShane (1994), pp 27–28; Hilton (1969), p125; McShane and Tarr (2003), p 186; Chandler (1977), p 192 (quote).
[17] Chandler (1977), p 193.

overhead systems were erected except for a few places such as parts of Manhattan.[18]

The majority of street car railways were private ventures, developed out of old horse car lines or were built by investors speculating in real estate. Property values tended to increase in the vicinity of the railway. A new trend appeared in the 1890's when small lines merged into local monopolies. The new electric lines operated at a much larger scale than the horse car lines geographically due to the higher speed of the electric tram, and this had consequences on the structure of the business. Small enterprises were combined into larger companies where professional managers rationalized the service, as operation became more complex and required careful scheduling. In New York, for example, the Metropolitan Street Railway Company was the result of mergers that led to complete control of the street railways of Manhattan and the Bronx in 1900.[19]

At first salaried managers shared top-level decisions with entrepreneurs who created the consolidated system. "Later they were replaced on the board of directors with investment bankers whose firms sold bonds to finance expansion, and by public commissions or municipal governments which increasingly took the responsibility for financing and constructing the growing systems." There were cases of bribery when giants got monopoly control over a city's network, and strikes and boycotts from employees and riders when services were cut down or free transfers were eliminated. A boycott in St Louis in 1900 lasted for weeks, but the struggle was won by the company. After similar struggles in other places the public lost sympathy for traction companies.[20]

Traction companies not only connected downtown with the suburb, they extended their lines to small towns in the region and even other cities. It was possible for people in Muncie, Indiana, to go to Chicago or even Buffalo, or for New Yorkers to go to places in New England or even Chicago. Interurban lines were growing during the first two decades of the 20th century, particularly in Indiana, Ohio, Pennsylvania, Illinois. Iowa, Utah and California. The length of interurban tracks increased from 3391 km in 1900 to 25,070 km in 1916.

Trolley lines became a link to a wider world and opened up for new forms of entertainment. Electric railways offered the possibility of taking a job in another town, of choosing a school at another trolley stop, or shopping in the larger city. The traction company ran special cars to theaters and sporting events, they rented out cars for parties. Such interurban rides became an important form of tourism as they were inexpensive and reached areas not covered by railroads. Day trips were popular as they permitted factory workers to take picnics or walks in the country. Traction companies created amusement parks themselves. They produced their own electricity, so electrified parks near the power house could use idle generating capacity in evenings and increase ridership during slack periods.[21]

Until the 1920's electric railways continued to expand and offer affordable urban and interurban travel. But in the long run they surrendered to other modes of transport, such as automobiles, buses and subways. Virginia Scharff has shown deep dissatisfaction among customers, especially in Los Angeles where car intensity reached high levels. Passengers complained that cars made too few runs, ran late and were often packed with people, and women complained about sexual harassments. The street railway companies had responded to a strike in 1919 by bringing in incompetent strikebreakers who endangered the lives of passengers. Newspapers reported about pickpockets and conductors who had thrown off passengers from moving cars. Bad experiences like this can explain protests in 1920 against the suggestion from local authorities to solve the problem of congestion in the downtown area with a parking ban. Women started a boycott of downtown stores and a committee organized an automobile parade and asked business owners to join them. Even though protesters defended the city center in this particular battle a transport system based on the automobile had decentralizing tendencies on the American urban landscape in the long run.[22]

This narrative about public transport in the USA teaches us six things: As long as city traffic was dominated by horses steam vehicles of all sorts were met with resistance; Horses were paradoxically part of the new, modern and urban world, literally pulling public transport through its first stages; A development block of street car and battery manufacturers was hampered when there were so few battery street cars in operation; Interurban railways was an existing alternative to touring by bike or car (more on this below); Monopolies and trusts among traction companies made individual mobility seem even more advantageous; Unsafe rides on street cars made the automobile look a safe private room in the public space for women.

B. Vehicles for tourism		
B.1	Bicycle	
B.2	Automobile	
	B.2.1	Steam cars
	B.2.2	Electric battery cars
	B.2.3	Internal combustion engine cars

In 1880 the *League of American Wheelmen* (LAW) was founded as a national association of clubs and promoter of cycling and good roads. When the Safety bicycle was introduced in the USA in 1887 came a new and broader wave of enthusiasm for cycling that

[18] McShane (1994), pp 27–28; Schallenberg (1982), pp 221–243; McShane and Tarr (2003), p 187; Hilton (1969), pp 126–127.
[19] Nye (1990), p 90; Schallenberg (1982), p 260.
[20] Chandler (1977), p 194 (quote); Nye (1990), pp 97–104.
[21] Nye (1990), pp 8–12 and chapter 3.
[22] Scharff (1991), pp 152–164. See also Davis (1995) on passenger's experiences of public transport, and Flink (1990), pp 140–143 on the interurban railway as forerunner of urban sprawl in California.

reached its zenith during the last years of the 1890's.[23]

Only fragmentary data exists in the literature on the number of bicycles in the US. It is said that the number of manufactured bicycles was 200,000 in 1889, one million in 1899, and 160,000 in 1909. If we assume that production increased and decreased smoothly between these years, and that each bicycle lasted ten years, a stock of bicycles can be estimated and related to the number of households for the years shown in Table 1. In that table the same relative number for cars is shown.

The table supports, albeit on shaky statistics, the 1890's as the period of "bicycle craze". Even though cycling originally was something for the young, athletic, with high income and plenty of leisure time, this leisure spread to a broader layer of the population. Cycling was a phenomenon among urban people, so to speak rediscovering the countryside by way of touring.

One obstacle for cyclists was bad roads. Since road pavement was underdeveloped when transport investment had been channeled in favor of railroads and railways, roads were often dirt roads or, at best, macadam roads. Cyclists took initiatives to build and finance "pleasure routes" themselves. The most famous cycle path was Coney Island Cycle Path built in 1894 linking Brooklyn with Coney Island, a distance of 5.5 miles (8.8 km). In June1896 a return path was built, and this was opened with a gala parade organized by the Wheelmen, attended by 10,000 cyclists and about 100,000 spectators.

Hiram Percy Maxim, who was hired by Albert Pope in the early 1890's to build cars, wrote about his discovery of the car in the bicycle when he was taking a ride of six kilometers between Salem and Lynn, two towns north east of Boston in 1892:

> Here was a revolutionary change in transportation. My bicycle was propelled at a respectable speed by a mechanism operated by my muscles. It carried me over a lonely country road in the middle of the night covering the distance in considerably less than an hour. A horse and carriage would require nearly two hours. A railroad train would require half an hour, and it would carry me only from station to station. And I must conform to its time-table, which was not always convenient.[24]

Bicycle enthusiasm died faster than it was born. Membership in the *League of American Wheelmen* reached a top in 1898 with 102,636 people. Already in 1900 the number was down to 76,944 and in 1902 there were only 8629 members left. The value of the bicycle industry's output was 2.6 million dollars in 1890, 31.9 in 1900, and 5.2 in 1905. A new gadget was in sight, the automobile. Leisure touring was transferred to the motor vehicle.[25]

The bicycle, and the "craze" of the 1890's, was the first horseless vehicle for individual mobility. Touring was an important part of bicycle use which linked it up to a broader romantic and naturalistic movement of "hiking" and establishments of national parks. Urban people discovered the countryside and nature without having to adjust to timetables or travelling with strangers. Without the bicycle, or if it had been confined to only urban use, the expectations on the automobile of individual (family) mobility for touring may have not appeared. If so, car culture may have developed slower and the outcome between steam, electric and ICE cars may have been different. Later on, in the 1920's, the train-hotel-holiday system was replaced by the car-hotel-holiday system, as Mom described, an indication that touring was a great force behind automobilism.[26]

Germany and France lay ahead of America on automotive technology, so early cars in the USA were imported. Soon inventors tried to construct their own automobiles, and they could find protection, not only behind freight costs over the Atlantic, but also due to the tariff of 45 percent on passenger cars. This tariff was reduced in 1913 to 30 percent on cars valued under 2000 dollars, and in 1922 changed to 25 percent or equal to that imposed by the exporting country, and in 1930 reduced to 10 percent. Imported cars amounted to only a small share of total supply of cars to the US, between 0 and 4 percent 1901–1912.[27]

People with lots of money and leisure imported expensive cars from Europe for the joy of driving fast and showing off. With this new toy, added to the race-horse and the sail-boat, they could drive almost as fast as the train, but without adapting to time-tables, tracks and stations. Touring freed from having to travel by a fixed route and with other people made it possible to explore vast spaces between railroads. Newspapers reported widely of these exploits and of car-exhibitions like that in New York in 1900. Publicity influenced all consumers, creating envy and hostility at the same time.

Conspicuous car use was socially destabilizing, it marked a gulf between the haves and the have-nots. "The story begins with what may have been the greatest class provocation in American history", McCarthy wrote. The arrogance of early rich drivers that scared horses and put pedestrians at danger and the general disregard of other users of the road, outraged the public. Anger and even violence met the early cars, such as stoning, "tire puncturing instruments" and even the use of shotguns. Anti-automobile laws were introduced such as speed-limits. Opposition to automobiles generally, and especially among rural Americans, was not a response from the narrow-minded, according to McCarthy: "On the contrary, ordinary people saw aggression from early automobile drivers as a threat to their social standing, masculinity, and dignity, and responded with understandable anger".[28]

A change of attitude towards the car occurred in the latter half of the first decade of the 20th century. Clay McShane studied what the New York Times wrote about cars during this decade. He could see a change after 1904, from mainly negative reports and limited advertising, to more conciliatory and forgiving reports and more advertising. James Flink also detected a change in attitude associated with reports on the earthquake in San Francisco in 1906 when motor vehicles were used in rescuing missions as horses could

[23] This section builds mostly on Reid (2015), with additional information from Bijker (1995), p 98; Smithsonian (2016); Chapot (2001); Quinn (1968); McShane and Tarr (2003).

[24] Originally from Maxim's memoirs, *Horseless Carriage Days* published in 1937, cited from Hounshell (1984), p 214.

[25] Quinn (1968), p 38; Rosenberg (1976), p 24.

[26] Mom (2015), pp 328–335.

[27] Flink (1990), pp 44, 253; Flink (1970), p 60.

[28] McCarthy (2007), Introduction and chapter one, quotes p xvi, 11 and 14.

Table 1
Estimated number of bicycles and cars relative to households. Per cent.
Sources: US Bureau of the Census (1975), part 1, p 41; US Bur of the Census (1975) part 2, p 716; Smithsonian (2016); Chapot (2001); Quinn (1968), p 38.

Year	Bicycles	Cars
1890	3.5	
1900	33.7	0.1
1910	20.6	2.3
1920		33.4

not distribute supplies or tow vans after the horses pulling them had expired from heat and strain. Standard Oil donated 15 000 gallons of fuel for these cars. Another change, or rather an indication of growing use of automobiles among non-rich people, is the drop after 1908 in the number of car-owners that hired a chauffeur. Data from the state of New York showed that before that year two out of three owners had a chauffeur, and after the rate was falling to one of three. The car was not only a rich man's toy anymore.[29]

3.1. The electric path

Car models sold in larger number were the small vehicles Oldsmobile Curved Dash and Locomobile, the former a gasoline car with a design of a horseless carriage, the latter a steam car with bicycle wheels. Electric cars were produced too, for example Electrobat by Henry Morris and Pedro Salom who started production in 1894. Morris and Salom had previously worked at a traction company so they knew that lead acid batteries limited the range of a battery car. They contacted the Electric Storage Battery Company which would presumably be interested in batteries for small cars when demand from street cars had been lost as local public transport invested in the overhead system. A new company was established, later named the Electric Vehicle Company, which began its business as provider of taxi-services on and around Manhattan in 1897. These cars looked like, and competed with, existing horse drawn cabriolet carriages. EVC got a good reputation in late 1898 when electric cabs could cope with a snow storm and handled calls forwarded from horse-cab companies. In January 1899 EVC had 45 cars in service and another 40 leased to patrons under long-term contracts.[30]

Now an electric car bubble was blown up. EVC was transformed to a syndicate in which the Metropolitan Street Railway Company and big electric utilities of New York, beside EVC, took part. The idea was to start regional companies for cab services and selling private electric cars in no less than seven large city areas. At first 1 600 vehicles, about a fourth of total auto manufacturing that year, were ordered, later raised to 4 200! A year later the bubble burst. In early 1900 a report was published about a series of battery tests made in France. All batteries showed bad results and no battery lasted longer than six months. This death blow to the grandiose EVC project added ammunition to the campaign by Horseless Age, a motor magazine, which had accused the "Lead Cab Trust" of a "rotten foundation". The tests seemed to confirm this, but perhaps the muckraker's critique of trusts and monopolies at the time, supported by the president, played a significant role in this disclosure. The EVC had bought the so-called Selden patent in 1899, and argued that this patent gave unique right to all internal combustion-based technologies. This comes close to admitting the disadvantages of the electric car compared to gasoline cars. The EVC changed its name to New York Transportation Company in 1901 and stopped using electric cars altogether in 1906. Now they used gasoline cars instead.[31]

After the French battery tests the Electric Storage Battery Company began seriously to design a special traction cell. Already in 1900 ESB presented a non-Chloride battery named the Exide, for which the details of the design were obtained from other companies and inventors. This was a radical departure from the company's past practice. A modified version, with three times the life of the original, was presented in 1911. The "Ironclad Exide" became the standard for storage batteries used in electric vehicles until the early 1950's.[32]

B.2.2 Improving the electric battery car	
B.2.2.1	ESB: Exide battery
B.2.2.2	Edison: Miracle battery
B.2.2.3	Ford & Edison: Ford electric

Thomas Edison put a lot of effort in developing the much sought after "miracle battery". He had his own incentive, namely the defense of direct current in the "battle of the currents" in the 1890's. Edison had developed his own system around the incandescent lamp and direct current and saw that electric cars as major consumers of urban-generated electric current would slow down the

[29] McShane (1994), pp 174, 183–184; Flink (1970), pp 45–46; Mom (2015), pp 109–110.
[30] Schallenberg (1982), pp 222, 250–255; Kirsch (2000a), pp 41–49.
[31] Schallenberg (1982), pp 264–266; Kirsch (2000a), pp 50–84; Flink (1990), pp 51–53; Cowan and Hultèn (1996).
[32] Schallenberg (1982), pp 267–271.

conversion to alternating current. He started his battery project in 1898, but the problem was quite difficult to solve. Not until 1909 did he present his alkaline cell, and its performance was not very much better than the lead-acid type.[33]

Henry Ford and Thomas Edison announced at an automobile show in January 1914 that they would put a "Ford Electric" with a range of 160 km on the market for $900. Edison even mentioned a price range of $500–$750, well below that of existing electric vehicles at that time. According to Mom the Ford Motor Company distanced itself from this idea, stating that the electric was "Mr. Ford's personal project", while Kirsch notes that archival material testifies to an enormous public interest in the project. But it ended with just a few prototypes, and instead Edison and Ford chose to work on an electric starter for the Model T, which was realized in 1919 seven years after Cadillac.[34]

A door was closed when the possibility of a development block embracing battery and car manufacturers was marginalized. Instead storage battery technology became subordinated to the needs of the gasoline car and its starter motor. André Gunder Frank coined the concept of "underdevelopment" in the 1960's, referring to a dependent development of the Latin American economies in relation to the metropolitan countries. Even though it is not a matter of countries or a colonial type of relation, there is nevertheless a similarity here. Compared to what might have been – a development of the battery as the main prime mover of vehicles – the starter motor for an ICE-car is a help function, and the development as such directed interests and search in the battery industry towards another path. This also confirms Schallenberg's evolutionary view of the battery industry: "…the readiness with which the technology has been adapted to new needs".[35]

3.2. The gasoline path

Henry Ford, a farmer's son, knew well what the ordinary man in the countryside and in small towns wanted, and shared the suspicion and hostility towards the wealthy. Ford deliberately turned away from the wealthy and towards rural America. And he knew that if he could reach out to them, the urban middle class would buy an affordable car too. The car must be both affordable and respectable, so in the Model T a low price was combined with respectable size. It had to be a big and powerful car, but very different from the snobbery of the early influential drivers. It was slower but safer than rich men's cars but bigger and stronger than small buggy-like cars.

While the rich found new hobbies in polo, flying and speed-boating, car culture changed with the enormous success of the T-Ford. Affordability was achieved in three ways: The price for a new Model T car was lowered radically, a market for used cars grew, and consumer credits became common in the 1920's (see Figs. 4 and 5). "The automakers actually met the consumers halfway", according to McCarthy. The use of cars was stimulated by the shortened work-week, and automobile tourism became a major recreational activity.[36]

General Motors and Alfred Sloan had to find a way to compete with the dominant Ford Model T, which had between 30 and 72 per cent of total passenger car production every year from 1913 to 1927 (see Fig. 3). Sloan feared that demand would be saturated and sales go down if there was no reason why people would buy a new car before the functional obsolescence of the old. A new strategy developed consisting of two elements: First, what Sloan chose to call "constant upgrading of product", later known as "planned obsolescence", was the annual model year changeover. Second, Sloan called GM to build "a car for every purse and purpose", which meant diversity in what the concern had to offer, a car brand and model for each segment. In the 1920's car ownership was so common in the US that ownership by itself no longer conferred status. Social distinction now would come only with having a car that was better than one's neighbors'. This was a return to the era that existed prior to the appearance of the Model T.

But the choice between three types of cars was not settled until the price of the Model T had made it affordable among farmers and broader layers of the population (see Figs. 5 and 6). Numbers matter here: In 1908 alone there were as many cars sold as there were in the five year-period 1900-04 put together, and in 1910 almost three times as many as in 1908, and in 1913 more than twice as many as in 1908. For the period 1909–1927 Model T had a 40 per cent share of all cars produced in the USA (see Fig. 3). The future for the automobile, in terms of propulsion system or dominant design, was not settled before sales took off in the 1910's. A successful initiative could narrow the definition of what the car should be, and did.

Farmers had experience of power-driven machinery before, according to Berger, especially the stationary gasoline engine, and were capable of repairs themselves. Oil and gas could be bought in large quantities at wholesale. The car could function as a prime mover to saw wood, pump water, generate electricity, run small grain mills and unload hay. The Model T was practical from the farmer's point of view: It was high enough to cope with ruts and ditches, and was composed of standardized parts available in the smallest of towns. It needed no special gasoline, it could be lifted for changing a wheel. And it was a device for leisure-time pursuits, the church and education became accessible to the rural family, family members could go to the nearest town for shopping, etc. The share of American farms owning a car rose from about 14 per cent in 1911, to 26 in 1920 and 58 in 1930 (see Fig. 6).[37]

Many authors have searched for possible alternative paths that would have changed the course of automobilism, mostly in favor of the electric. In fact, Ford and the Model T did change the course, with different characteristics compared to some previous models: Low emphasis on speed and luxury and high on the practical side of a car. With lowered price for a "big" car Model T became a huge

[33] Schallenberg (1982), pp 352–372; Kirsch (2000a), pp 196–201. Mom (2004), pp 212f, gives a more positive picture of the new batteries.
[34] Kirsch (2000a), p 200; Mom (2004), p 255.
[35] Frank (1966); Schallenberg (1980), p xi. This evolutionary view seems to have been independent from that of Nelson & Winter.
[36] McCarthy (2007), pp 1-54, quote from p 41.
[37] Berger (1979), pp 31–53. See also Kline and Pinch (1996).

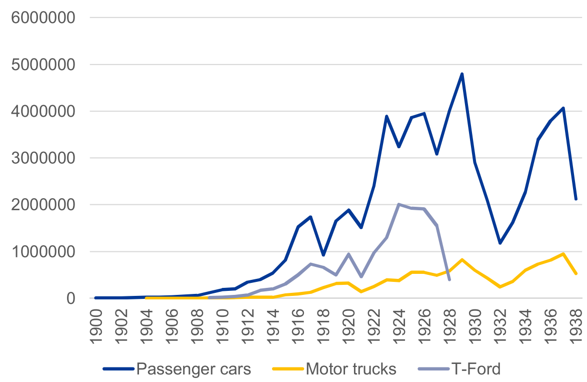

Fig. 3. Number of passenger cars, T-Fords and motor trucks produced in the USA.1900–1938.
Sources: US Bur of the Census (1975) part 2, p 716; Wikipedia (2016). Ford Model T are included in "Passenger cars".

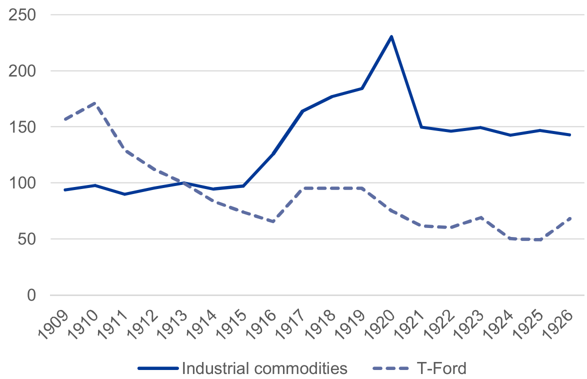

Fig. 4. Price index for industrial commodities in general and for the Ford model T. 1913 = 100.
Sources: US Bureau of the Census (1975), part 1, p 199; Wikipedia (2016).

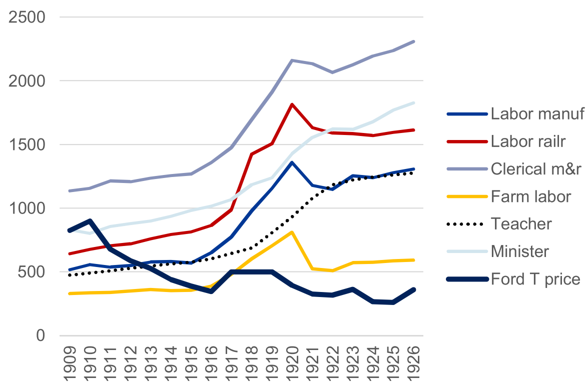

Fig. 5. Annual earnings and price of Ford model T 1909-1926. Dollars.
Sources: US Bureau of the Census (1975), part 1, p 168: Wage earners manufacturing; Wage earners steam railroads; Clerical workers manufacturing and steam railroads; Farm labor; Public school teachers; Ministers. Wikipedia (2016): Price Model T Runabout.

success even beyond the targeted group. Initiatives from manufacturers, or supply-side actors generally, play a significant role, and can change the definition of an innovation.

Touring was an important use of the automobile, a way to explore the nation, or "See America First" as the patriotic slogan formulated it. Cost calculations presented in 1914 showed that it was cheaper for a family to travel by car than by train, especially if tent and canned food replaced hotels and restaurants. In 1915 over 44 000 people arrived at Yellowstone National Park by train, while just 7 000 came by auto. By 1930 figures were inverted, when 28 000 arrived by train and 195 000 by car. Automotive tourism was impressive, according to Mom: In 1928, out of 20 million cars registered 11 million participated in summer tourism involving 44 million individuals. Cars overtook railroads as main transportation to national parks by the mid 1920s, earlier than the car became the norm for commuting: "… the pleasure of the family trip seemed to dominate interwar car culture".[38]

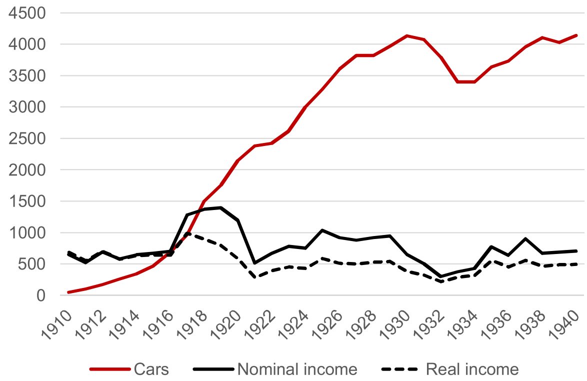

Fig. 6. The total number of cars on farms, average farm income in nominal and real (1913) terms in US dollars.
Source: US Bureau of the Census (1975), part 1, pp 210, 211, 469, 482, 483.

B.2.3 Choice of internal combustion engine		
B.2.3.1	Low compression engines	
	B.2.3.1.1	Ethanol, or blend gas + ethanol
	B.2.3.1.2	Thermal cracking
B.2.3.2	High compression engines	
	B.2.3.2.1	Ethanol, or blend gas + ethanol
	B.2.3.2.2	Gas + lead additive

Ethanol could have been the fuel for cars with internal combustion engines. Nicholas Otto, the inventor of the modern internal combustion engine, used ethyl alcohol as fuel in his machine to start with. The later “Otto-cycle” engine was made primarily for gasoline, but was still adaptable to ethanol (and benzene from coal).[39] Car manufacturers in the US had an ambivalent attitude as to what fuel to use. Generally, they adapted motors for low-compression so that gasoline could be used, but at the same time left an option ready for ethanol. By way of a carburetor pure ethanol or a mixture of the two, could be used as fuel.[40]

In the 1890’s fuel oil was used more widely, for boilers in factories, locomotives and ships. Now there was fear that electric light would undermine the commercial foundation for the oil industry, but a little later sales of internal combustion cars were increasing. Fear of oil running out was always there as use of oil products increased as fast as new oil fields were discovered. The problem now was that new oil wells did not contain the lighter fractions where natural gasoline was found. With existing know-how at the time the highest yield of natural gasoline from a barrel of crude was 15–20 per cent. Another problem was that the tax on ethanol was repealed in 1906. It was a repeal of the tax on “industrial alcohol” so it got support from President Theodore Roosevelt, a bitter foe of the oil industry, and of the temperance movement. However, the price for ethanol seem to have been higher than that of gasoline, even excluding the denaturing additive.[41]

Still, the oil industry had a refining challenge ahead in order to meet increasing demand for gasoline when the crude had only a small share of natural gasoline. The challenge was to “crack”, or break down, the larger hydrocarbon molecules into smaller ones that could provide auto fuel. The refinery manager of Standard Oil, William Burton, started experiments with “thermal cracking”, combining pressure with high temperatures, in 1909. Production started in 1913 and was a huge success, doubling the yield of gasoline. Costs were reduced by 28 per cent, eventually by half when further improvements had been made. Thermal cracking came precisely at the moment when it was needed. The oil industry was facing a gasoline famine – the price of gas increased from 9.5 cents in October 1911 to 17 cents in January 1913.[42]

A new opening for ethanol based on agrarian produce came after World War I. Due to mechanization and artificial fertilizers, together with a glutted grain market, American farmers faced difficulties unless new markets were opened up for their commodities. During the war grain production had been stimulated by demand from Europe, but now there was overproduction. However, ethanol did not become the “fuel for the future”. Despite that Ford’s model T could easily be adapted to ethanol gasoline eventually won out.

One person was important in this struggle, Charles Kettering, vice president of research at General Motors and president of the Society of Automotive Engineers. Kettering’s motive, according to Loeb, was at first to save the car from gasoline shortage, but he argued that enormous amounts of land would be required for pure ethanol as fuel for cars. High compression engines could be up to 50 per cent more energy efficient, but the problem of “knock” put an upper limit on compression. Knock can damage the engine so

[38] Harmon (2001), pp 62–68; Mom (2014), pp 303–304.
[39] Kovarik (1998), pp 8–9.
[40] Carolan (2009); Smil (2005), p 128.
[41] Yergin (1991), p 51, 87, 111; Kovarik (1998), p 11; Carolan (2009), p 425.
[42] Yergin (1991), p 112; Freeman and Soete (1997), pp 92–93.

manufacturers sacrificed the efficiency of high compression, but with the electric starter motor a door was opened for engines with more cylinders and higher compression ratios that many individuals would have found difficult to crank by hand. Fuel efficient engines could mean smaller engines without loss of power or range. It could also mean more power and range, and according to Loeb this was what happened when Sloan's strategies for General Motors was adopted. In 1921 Kettering found a solution to the knock-problem: Tetraethyl lead as an additive. However, there were serious health problems connected to lead so the federal health authority did not approve of leaded gasoline until 1926.[43]

Still, it is a mystery why ethanol as an alternative remedy for knocking did not succeed. Until the discovery of Black Giant in eastern Texas in 1930 there was fear of energy shortage. This had to do with increasing use of fuel for automobiles in the 1920s. In 1919 USA used 60 billion liters of oil, ten years later 160 billion. The number of cars increased fast from 6.7 million in 1919 to 23.1 million in 1929, and each car was driven longer distances, on average 4 500 miles in 1919 and 7 500 in 1929.[44]

For a long time the future was open as to what car and what fuel would be dominant. The T-Ford probably locked the car to the internal combustion engine in the 1910's, and ethanol was not ruled out until leaded gasoline won the battle. One sign of the openness of the period was gasoline distribution. Drive-in gas stations did not appear until the 1920's, according to Yergin. The first drive-in in St Louis 1907 he calls a "dump" as that, and others, were very simple selling points. Most gasoline was sold by storekeepers over the whole country who had cans of motor fuel without brand below the counter or in the back of the store: Grocery stores, general stores and hardware stores. From 1920 to 1929 this changed completely, all gas was sold at gas stations or garages. Obviously, storekeepers could just as well have kept ethanol or mixed motor fuels below the counter.[45]

4. Discussion

4.1. Kirsch and Mom on the electric car

David Kirsch and Gijs Mom discovered that they were writing dissertations on the same subject in the 1990's, and they started an exchange of ideas. Eventually they ended up with one book each on the electric vehicle in 2000 and 2004 respectively. Both studies are filled with facts on electric vehicles, including trucks, based on business and government documents, motor magazines and previous literature. While Kirsch studied the American experiences, Mom added examples of electric vehicles from some European countries, for the period until the mid- or late 1920's. Both authors shared the view that the choice between steam, electric and internal combustion engine (ICE) passenger car was settled already in the early years of the 1900's in the USA (see Table 2).

Despite an impressive amount of facts around electric cars and cars in general discussions on the importance of Ford's Model T is neglected. When "take-off" occurred in the 1910s this model was in the lead, and the choice of propulsion and fuel for this model was probably decisive for the future.

The story of the EVC 1899–1900 was that of a development block where street car, battery and utility businesses promoted electric taxis and leases of electric cars as complements. This was not a bad idea considering that electricity was an expanding technology at the time. It would be unfair to judge the electric car, in comparison with the gasoline car, based on the exaggerated plans of the EVC, but battery technology and dislike of trusts in general must be part of the explanation.

The battery was the weak point of the electric car, as short range eliminated touring capacity. The counter-argument of Kirsch and Mom on the battery as a decisive characteristic is that most trips were short. This is of direct relevance also today as most trips by car come within the range what an electric car can provide. In the words of Mom: "One can imagine a society with a dense charging infrastructure, in which the subculture of the civilized electric car has become the dominant culture, and in which the car with a combustion engine is rented for rare trips out of town". And Kirsch wrote about legitimate uses of electric cars today: "… as second cars for families that already own a gasoline automobile for long-distance travel."[46]

A car culture in which the city car is the normal expectation would have led to a different outcome in terms of propulsion system, is the point Kirsch and Mom want to make. The problem with this is that it is not an explanation at all, but rather a "rescue from the burden of history" of the electric automobile, a standpoint from which existing car culture can be criticized. However, it is difficult to reconcile lack of electrification of rural USA[47] and increasing motorization of rural people, with prospects of a city car alternative. Even though the car seldom was used as a touring car it was used as a touring car sometimes – the gasoline car could be used as a city car too. What we can do in social sciences is to try to explain why this choice was made, while denying actual choices must end up in blaming consumers and other actors. Mom wrote: "… it cannot be denied that studies emphasizing the 'love affair' of Americans with the car tend to accept the basic systemic presuppositions of the car culture."[48] This is untenable. Somehow decisions were made concerning car use, propulsion system and fuel type or blend, and these must be treated as historical facts worthy of explanation, not necessarily proof of something desirable.

It is probable that touring made users discover the advantages of individual mobility, to go whenever and wherever one wanted from door to door, of not having to adjust to fixed time-tables, routes and stops. There are differences between public and individual

[43] Carolan (2009), p 431f; Kovarik (1998), pp 18–21; Loeb (1995).
[44] McCarthy (2007), p 20.
[45] Yergin (1991), p 209.
[46] Kirsch (2000a), p 186, 208; Mom (2004), p 299.
[47] Kirsch (2000a), p 177.
[48] Mom (2015), p 14.

Table 2
The number of cars produced in the USA in 1900 and 1904.
Source: Mom (2004), pp 31, 113.

	1900	1904
Electric cars	1,575	1,425
Gasoline cars	936	18,699
Steam cars	1,681	1,568

transport. But the actual mix of the two modes was probably made more in favor of individuality in the US due to the bad reputations of monopolizing railroad and railway companies. Concentration of people to big cities cannot reasonably favor individual mobility. That the car conquered the American city must have been despite limited space for individual vehicles. Interurban railways expanded into the 1920s and held a real alternative to the American level of "love affair" with the car.

Another theme from Kirsch and Mom is hybridization. They see two kinds of hybrids: One has already been dealt with, at the level of large system, or transport regime, the distinction between city and touring (or rural) travel; And at the level of small systems, or vehicle, a mix of electric and non-electric components.[49] The idea that the car of today is "… a specific type of technological hybrid that incorporates important attributes of both electric and internal combustion designs." Kirsch implied here that the mix of the car as a hybrid could have been different, more electrical, because "the electrification of the automobile emerges as significant long-run trend". It all started in the 1910s when a big internal combustion engine was assisted by a small electric motor and a charging system for starting, lighting and ignition.[50] It is more obvious today than in the late 1990s when Kirsch wrote his book that hybrids are one important way to get closer to the electric car. However, electric components as assisting components was part of a certain path in which internal combustion was dominant. It is a kind of "underdevelopment" of the battery when technological development is directed to a subordinated role.

4.2. Schot, Kanger and Verbong on the user

When Schot, Kanger and Verbong declare that user participation in transitions of energy systems "extends far beyond making purchasing decisions" it is perfectly in line with the perspective chosen in this article. And, furthermore, that users themselves play an important role in the construction of user needs.[51] However, as already indicated in Section 2.4, there is a fundamental difference between products, such as cars and mobile phones, with which the user can explore and experiment with possible uses and in that develop his or her social and everyday life on one hand, and other products, such as fuel or "solar collectors, biomass heating systems, sustainable buildings and wind turbines" on the other. The user can be an active user for some products, but only a passive user, or rather receiver of energy services, in some other. Even though this is, to some extent, a matter of degree in that there are products more or less in between active and passive use but, nevertheless, the distinction is important. It is hard to imagine enthusiasm or a "love affair" with energy carriers or energy technologies like photovoltaics of a similar kind to that we have seen in relation to the car and the smart phone.

It is understandable that the authors prefer to deal with users in terms of "user roles" and "embeddedness" when it comes to 'boring' products. For 'exciting' products this is not accurate as the agency, or activity and initiative, of the user is lost. The creative user disappears when something pre-determined, "roles", are used as concepts. With 'exciting' products the user can develop daily practices, while "embed in daily practices" implies conservation of traditional life.

4.3. Geels on pathways

One type of transition pathway is the "de-alignment and re-alignment pathway". It is based originally on an article by Frank Geels on precisely the same topic as this article, the emergence of the car in the USA, later condensed as an empirical example of the type. The idea behind "de-alignment" is that the traditional horse-based transport regime was in crisis and erosion in the late 19th century. Then, according to Geels, followed a rather long period where several new technologies existed side by side because there was no clear substitute, and only eventually did the car take a prominent position, "re-alignment".[52]

Already the starting point is wrong: Horses were not only part of the old regime. Buses and street cars were new and they were pulled by horses. The number of horses actually increased very much until the 1890s when Sprague had demonstrated the practicality and economy of electric, horseless, propulsion. The reasons for resistance and enthusiasm for the bike and the car was quite different, and not traditional at all. It was not a matter of a fixed set of needs of transport, but development of mobility patterns revolutionizing everyday life, or rather Sunday and summer life, as the bike and the open car were used for touring.

It is not clear what Geels meant with "alignment". From a development block-perspective alignment is quite clear: The electric block failed and so did the ethanol block, while the gasoline block was successful. Alignment with active users was important, as has

[49] Kirsch (2000a), pp 209–227; Kirsch (2000b); Mom (2004), pp 296–301.
[50] Kirsch (2000a), pp 5, 10, 210, 226.
[51] Schot et al. (2016).
[52] Geels (2005); Geels and Schot (2010), pp 63–68.

been discussed above. Despite high costs, bad roads and an expanding railway system, enthusiasm for individual mobility carried the novelty from niche to regime in thirty years.

5. Conclusions

5.1. How could the car be so successful?

Considering the trouble and costs bad roads meant for users, barriers for entry were enormous. There were also resistance and restrictions in cities such as speed limits. Behind this were norms related to expected use of streets and roads. There must be a force that can raise a technology from nothing to something that had become common in the 1920's, and eventually transformed American society.

Different types of cars were nurtured in niches. The conspicuous consumption of the super-rich suggested a car culture focused on racing and speeding. There were also small cars, not very different from buggies with engines instead of horses, and some others resembling bicycles. The bicycle craze of the 1890's suggested touring as the purpose of the car, something supported by the many reliability runs where drivers and manufacturers proved to the public that a car could go long distances, even from coast to coast. Until the success of Ford's Model T during World War I car culture was open for several development paths and volumes.

In order to understand and explain the formidable popularity of the car, we have to see the agency on both sides of the market. It was not merely a replacement of the horse and buggy, a shift from animate to inanimate power for the same needs. It was not "consumption", but the work of an active user. The one that explored what the new technology could bring about, an extension or development of needs that manufacturers could not foresee. The literature tells us a lot about amusement, such as Sunday picnics and camping, visiting family and friends, or just going for a ride in the countryside. This enthusiasm can be seen already in the use of the bicycle. Later the car also became a utility for commuting to and from suburbs.

Public transport cannot by its very nature open for individual mobility – the user has to "conform to its time-table" as H. P. Maxim said. With a car the user can go wherever and whenever he or she wants. Allowing private monopolies for street cars, and consolidation of businesses into giant corporations, seem to have made the public suspicious of trusts and monopolies, but this is not very well investigated in the literature.

Initiative from the supply-side is also important. The definite breakthrough came with Ford's Model T, deliberately targeting the farmer as user. It was an anti-car, negating the arrogance of the super-rich: It was slow to drive. To begin with it was a multi-purpose device for the rural population: Beside joy rides, a substitute for a stationary engine, for freight of farm produce, for shopping in town, etc. The low price for a new car was more important than rising average farm income during the war. The agency of the entrepreneur, Henry Ford, was decisive.

5.2. Why did the car with an internal combustion engine win?

It did not, the touring car did. Range thus became a qualifier giving the ICE-car an advantage as gasoline could be bought at many places. The electric car had no such supporting infrastructure, so range extension was concentrated to the possibility of a "miracle battery". The fact that Thomas Edison, with an impressive record of innovations and a personal interest to defend direct current, failed to bring about a battery making long range possible, is a convincing piece of evidence that the battery made the difference. The literature is less informative on the steamer, but this is less interesting today as it used the same fossil fuel as the ICE-car.

What we saw in the late 19th century was a missed opportunity for a possible development block, that of electric batteries and trolleys. For techno-economic reasons, and despite some resistance to overhead wires in cities, the battery trolley lost the battle. If it had not, battery improvement would have started much earlier, would have had many more interested parties and experiences of real battery vehicles to learn from. However, it is doubtful that the electric car could have become dominant: It would have required a slower development of automobilism so that the electric infrastructure had developed far enough to support a battery-switching or -charging system. Another scenario is that enthusiasm for touring could have been satisfied by extensions of street car lines into interurban connections, that actually did occur until the 1920's. However, alternative paths imagined are always speculative as empirical facts are replaced by assumptions. "Forks" stick to facts, make use of the open character of each historical point in time.

With the electric starter motor we got the "electrified gas car" or "hybrid car", as David Kirsch reminded us of. This eliminated the crank which was difficult or even dangerous to use as starter. It also made the battery industry into something that resembles what André Gunder Frank called *underdevelopment,* that is a development of batteries dependent and subordinated to that of the gas car. Development of the electric motor as prime mover was abandoned in favor of a support technology to the ICE-car. The term "hybrid" disguises the dependent character of the electric part of the electrified gas car.[53]

5.3. Could there have been another fuel for the winning car?

It would be too easy to say that the higher energy density of gasoline compared to ethanol determined the outcome, even though this is an important aspect. Internal combustion engines were adapted and adaptable to several types fuel, including ethanol and gasoline or blends of the two. Price information is quite fragmentary in the literature which makes it hard to determine what role

53 Kirsch (2000a); Frank (1966).

prices played. The price of gasoline probably fluctuated violently at times.

The dynamic "complementarities" Erik Dahmén saw as the central mechanism in *development blocks* are quite obvious in the case of the oil industry and the ICE-car. It points at the creation of development blocks, but not necessarily consciously: The political level played a role in regard to taxes on different fuels and the lax regulation of leaded gasoline. The most interesting part, and something it is hard to find a good answer to in the literature, is at the sub-political level, in regard to two possible alliances. Why one alliance, that between auto manufacturers and the oil industry, could win, while another, between auto industry and farmers, could not, is a very interesting topic.

5.4. Policy implications

A car culture cannot change if owners and drivers of cars do not want to change that culture, and this points to the need for debate in the public sphere with the possibility of people adjusting their own choices to what is required for sustainability to be achieved. Without this public will-formation policy instruments aiming at reducing car use will fail due to lack of legitimacy.

In 2015 the world average of motor vehicle density was 182 vehicles per 1000 inhabitants, and this resulted in 1.3 billion vehicles globally. The average density for the USA was 821. If this density is what the rest of the world is striving for, the end result will be 5.8 billion motor vehicles, or 4.5 times as many.[54] This puts a very heavy duty on improvements in fuel efficiency, and hybridization both of fuels increasing the share for sustainable biofuels and of propulsion system towards more of electricity. There are limits as to what technological improvements can achieve, so it is highly probable that we need to reconsider car use. If my interpretation here is right, the joy and freedom associated with the car will be hard to defeat in democratic societies and market economies.

For the realization of electrification of the transport sector it is essential that the electric car has the same performance capabilities as that of existing cars. Touring capacity make limited range and thus battery technology a reverse salient and critical problem to solve. If it is not solved the future will halt at hybrid propulsion solutions, or a combination of efficient engines and substitution of fuel. Fortunately, the historical case from the USA show no "love affair" with a particular fuel, or even propulsion system.

Public transport can never replace individual mobility, as the latter involves freedom from fixed time-tables, routes and destinations. But the mix between public and individual was probably biased in favor of individual mobility due to bad reputation of local monopolies of railway companies. This, in turn, point at the importance of city planning and public transport management.

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